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X-ray variability in the quiescent state of Cen X-4

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Abstract. We report on a ROSAT-HRI observation of the soft X–ray transient Cen X-4 during quiescence. We discover a variation in the flux by a factor of 3 in less than four days. This relatively fast variation, the first observed from a quiescent soft X–ray transient, rules out some of the emission mechanisms that have been proposed for the quiescent flux. Accretion either onto the neutron star surface or onto the magnetospheric boundary is clearly favored.

Key words: Stars: individual: Cen X-4 – X–ray: binaries – accretion

1. Introduction

The quiescent emission of Soft X–ray Transients (SXRTs) has been investigated for only 5–6 sources (e.g., Verbunt et al. 1994; Asai et al. 1996); this is characterized in all cases by very soft spectra (black body temperatures of a few hundreds of eV) and X–ray luminosities of $\sim 10^{32-33}$ erg s^{-1}.

Cen X-4 is one of the nearest ($d \sim 1.2$ kpc) and best studied SXRT. Two outbursts have been observed from Cen X-4 in 1969 and 1979. The most detailed observation of Cen X-4 during quiescence is the one recently obtained with ASCA by Asai et al. (1996). These authors reported a quiescent luminosity of 2.4×10^{32} erg s^{-1} (0.5–10 keV). The X–ray spectrum measured is well fit by a black body component ($T_{\rm bb} = 0.2$ keV; $R_{\rm bb} = 1.8 \times 10^6$ cm) plus a power-law with a photon index of 2–3. The contribution of these two spectral components in the ASCA energy band is comparable.

Here we report on a ROSAT HRI observation of Cen X-4 during the quiescent period.

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2. ROSAT observation

The ROSAT High Resolution Imager (HRI; David et al. 1992) observed Cen X-4 between 1995 August 16 and 26, for a net exposure time of 17469 s. The brightest of the ~ 10 X–ray sources detected in the field is at coordinates 14h 58m 21s.8, $-31^\circ 40' 3''.6$ (J2000), fully compatible ($< 3''$) with the position of Cen X-4 reported by van Paradijs (1993).

The average HRI count rate of $(1.3 \pm 0.1) \times 10^{-2}$ counts s^{-1} corresponds to a signal to noise ratio of 12. By adopting the black body plus power law model derived from the ASCA fit (Asai et al. 1996) and a column density $N_H = 6.6 \times 10^{20}$ cm^{-2} as estimated by van Paradijs et al. (1987) based on the optical reddening, we predict an HRI count rate of $\sim 10^{-2}$ counts s^{-1}. This is in agreement with our measurement and indicates that the average source luminosity is at a level similar to that measured with ASCA $\sim$ 18 months earlier. For these spectral parameters and a distance of 1.2 kpc, this count rate corresponds to a 0.1–2.4 keV X–ray luminosity of $\sim 7 \times 10^{31}$ erg s^{-1}.

To study the source variability, we extracted 393 counts contained in a circle of $20''$ radius centered on the source position. A periodicity search was carried out spanning periods from 10 ms to 100 s, with negative results. The corresponding upper limits are poor (pulsed fraction $\gtrsim 90\%$, assuming a sinusoidal modulation) due to the high number of selected frequencies and the limited number of counts. If the search is restricted around the

Table 1. ROSAT HRI Observation log.

Period begin (TJD)	Period end (TJD)	Exposure (s)	Count rate (counts s^{-1})
9945.631	9945.648	1502	$(6.8 \pm 0.7) \times 10^{-2}$
9950.065	9950.480	4320	$(2.2 \pm 0.2) \times 10^{-2}$
9953.589	9955.189	11647	$(1.6 \pm 0.1) \times 10^{-2}$

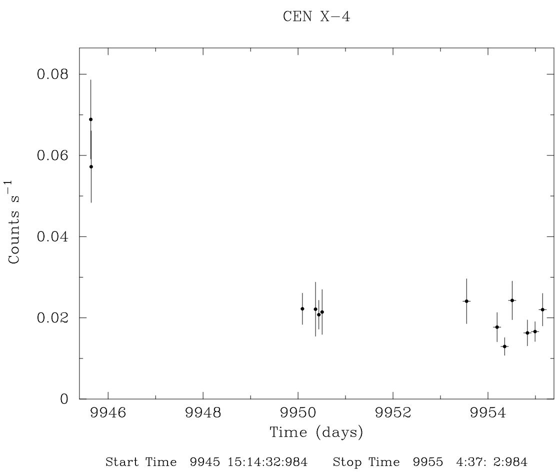

Fig. 1. X–ray light curve of Cen X-4. Different bin times were applied for the three observing periods.

32 Hz periodicity reported by Mitsuda et al. (1996) based on the ASCA GIS light curves, then an upper limit of 80% on the pulsed fraction is derived averaging together 6 power spectra of different time intervals, spanning 10 indipendent frequencies between 31.2498 and 31.2502 ms.

Significant aperiodic variability is clearly detected on a timescale of days. Indeed, a flux variation is apparent by comparing the Cen X-4 count rates obtained from the three separate time intervals of which the ROSAT observation is composed (see Table 1 and Figure 1). In the first interval a relatively high level of emission is observed, consistent with a flare-like event. This count rate variation affects mainly the soft channels of the HRI. In the other two intervals, separated by $\sim$ 4 days each, the source count rate is a factor of 3–4 lower and its flux is consistent with a constant value.

3. Discussion

In a reanalysis of the Einstein IPC (on 1980 July 28) and EXOSAT LE (on 1986 February 21) observations of Cen X-4, we find that both are consistent with a single value of the X–ray luminosity for spectral parameters comparable to those of ASCA (Asai et al. 1996), hinting to a constant X–ray luminosity over 15 years. Therefore the decrease in the X–ray luminosity found by van Paradijs et al. (1987) assuming a 1 to 5 keV bremsstrahlung spectrum seems less likely.

Our ROSAT HRI observation of Cen X-4 provides also the first evidence for a flux variation on a timescale of a few days in the quiescent flux of a SXRT. This variation is likely intrinsic to the source (no occultations or dips have ever been observed) and therefore it can help constraining the emission mechanisms during quiescence (Stella et al. 1994).

The possibility that the late type companion star accounts for the observed luminosity has been excluded by Verbunt (1996). Neutron star cooling is attractive in view of the spectral results consistent with thermal emission from a body of size comparable with a neutron star, however it is incompatible with the observed rapid decrease in the source intensity. Also the shock emission model in which the X–ray luminosity is produced by the interaction of the relativistic pulsar wind with gaseous material from the companion star encounters problems. The mechanism is likely at work in PSR 1259–63, where the X–ray spectrum is characterized by a power-law with photon index of $\sim$ 2 extending from 0.1 to 200 keV (e.g. Tavani & Arons 1996). In the case of Cen X-4 however, besides the power-law component, also a black body component is present. Moreover, the HRI count rate variation is mainly observed in the soft channels, where the black body component dominates.

We believe that the most likely explanation for the quiescent flux of Cen X-4 is that it derives from mass accretion. In this case variations in the accretion flow can easily explain the observed changes. Either accretion onto the neutron star surface and onto the magnetosphere can explain the observed properties, leaving open the possibility that Cen X-4 contains a fast spinning, weakly magnetized neutron star (Stella et al. 1994).

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References

Asai K. et al., 1996, PASJ 48 257
David L.P., Harnden F.R.Jr., Kearns K.E. & Zombeck M.V., 1992, The ROSAT High Resolution Imager (HRI) technical report, US ROSAT Science Data Center, SAO
Mitsuda K., Asai K., Vaughan B. & Tanaka Y., 1996, in *X–ray Imaging and Spectroscopy of Cosmic Hot Plasmas*, (Waseda Univ., Tokio), in press
Stella L., Campana S., Colpi M., Mereghetti S. & Tavani M., 1994, ApJ 423 L47
Tavani M. & Arons J., 1996, ApJ in press
van Paradijs J., 1993, in *X–ray Binaries*, eds. W.H.G. Lewin, J. van Paradijs & E.P.J. van den Heuvel, Cambridge University Press, p 536
van Paradijs J., Verbunt F., Shafer R.A. & Arnoud K.A., 1987, A&A 182 47
Verbunt F., Belloni T., Johnston H., van der Klis M. & Lewin W.H.D., 1994, A&A 285 903
Verbunt F., 1996, IAU Symp. 165, ed. E.P.J. van den Heuvel, p 333

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